The Economics of the Internet of Things in the Global South

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Abstract:

While the Internet of Things (IoT) is not new, its key components are becoming increasingly affordable now, which makes the technology extremely attractive for the Global South. By collecting data from various IoT sources, combining them with data from other sources and using big data analytics, decisions can be made and actions can be taken that can have important economic, social, ecological and environmental implications in these countries. The most visible impacts of the IoT in these countries include improvements in agricultural and food systems, enhancement of environmental security and resource conservation, achievement of better healthcare, public health and medicine, and enhancement of the efficiency of key industries. This paper provides an overview of how the IoT is currently being used in the Global South. It also discusses the opportunities and challenges that IoT initiatives present there. The analysis indicates that the IoT may address some of the institutional bottlenecks, technological challenges and key sources of high transaction costs. On the other hand, various sources of underdevelopment may act as barriers to full utilisation of the IoT.

Keywords: Global South | institutional bottlenecks | Internet of Things | micro-insurance | sensors | telemedicine and remote patient monitoring

Article:

Introduction

Earlier research has suggested that new and emerging technologies such as cloud computing have started to transform economic, political and social activities in the Global South.(1) For instance, South-based businesses are reported to be taking advantage of the pay-as-you-go model of the cloud, and of its scalability and flexibility features. Government agencies in the Global

South have been investing in cloud-related megaprojects. Cloud-based mobile applications have transformed the way cell phones are used in the Global South.

Just like its recent predecessors, the Internet of Things (IoT) is bringing fundamental changes in economic, environmental, healthcare, social and political realms in the Global South. Regarding the attractiveness of the IoT in addressing major issues facing the area today, it is worth noting the convergence of a number of trends, such as innovations in low-cost devices and sensors, scalable network connectivity, and maturity of mobility, cloud and big data models.(2) These enabling technologies have helped users realise the benefits of the IoT.(3) Perhaps the most encouraging trend is that IoT components, such as sensors, which were prohibitively expensive in the past, are now increasingly affordable and accessible to a broader population. For instance, sensors such as radio-frequency identification (RFID) tags cost just a few cents.(4)

Unsurprisingly there is a broad range of potential applications and uses of the IoT and these are likely to address key economic and social issues, such as improving agricultural and food systems, enhancing environmental security and resource conservation, achieving better healthcare, public health and medicine, and enhancing the efficiency of key industries. The IoT has already played a key role in protecting rhinos and elephants from organised poaching gangs' illegal exploitation, expanding micro-insurance services to low-income households, monitoring water supply and quality, and promoting energy efficiency and conservation in a number of countries in the Global South.

An encouraging development in the IoT sector is that some of the leading IoT companies are from the Global South. Perhaps the number of IoT-related patents is the best gauge of innovative activities in this field. In this regard, according to the UK Intellectual Property Office, during 2004–13, China's ZTE ranked #1 on a list of companies worldwide with the most IoT patents. ZTE had about 300 patents during the period. China accounted for 38% of all IoT patents globally.(5) It is also worth noting that many Chinese universities have started offering IoT-related courses such as a bachelor's degree in IoT engineering.(6)

In some economies the governments' proactive and coordinated support has been a key factor in promoting the development of the IoT industry and market. For instance, the Chinese government has established state-owned enterprise zones such as the Chengdu Internet of Things Technology Institute in Sichuan province. The institute is developing a health care system, which allows rural villagers to step into a telephone booth-sized 'health capsule' in order to get a diagnosis and prescription from a doctor in a distant hospital.(7) As of 2013 the institute had installed 11 'health capsules' in a city near Chengdu.(8) China has launched local and national initiatives to support research on IoT and apps that are likely to lead to adaptation of the technology to local conditions and circumstances.(9)

The objectives of this paper are to (1) provide an overview of how the IoT is currently being used in the Global South; and (2) take a look at the opportunities and challenges that IoT initiatives present to organisations there. Specifically we will consider how the IoT can address some of the institutional bottlenecks, the lack of human and physical capital, technological challenges and key sources of high transaction costs that have been identified as the main causes of underdevelopment.(10) The article also analyses how some of these factors may provide

opportunities for the development of the IoT industry and market in the Global South while others may act as barriers to full utilisation of IoT in Southern economies.

Before proceeding further, we provide some clarifying definitions. The IoT is the network of physical objects or 'things' (eg machines, devices and appliances, animals or people) embedded with electronics, software and sensors, which are provided with unique identifiers and possess the ability to transfer data across the Web with minimal human interventions. According to Gartner, there are three components of an IoT service: the edge, the platform and the user. The edge is the location where data originate or are aggregated. Data may also be reduced to the essential or minimal parts. In some cases data may be analysed. The data then go to the platform, which is typically in the cloud. Analytics are often performed in the cloud using algorithms. A real-time data streaming decides whether some actions need to be taken right away or whether the data need to be stored for future use. The user engages in a business action. There are three possible ways in which data that have been analysed can move from the IoT platform to a user: (1) the user deploys an application programme interface to call or query the data, which specifies how software components of the user and platform should interact; (2) if the IoT finds a predetermined set of events, it can announce or signal to the business user; (3) it is possible to combine (1) and (2).(11)

The paper is structured as follows. We proceed by first providing a review of relevant literature. Then we look at the economics of the IoT with an illustration from the insurance industry in the Global South. The section following this discusses the state of the IoT in the Global South. Next we provide an assessment of the opportunities afforded by the IoT before discussing the IoT challenges and risks. The final section provides discussion and concluding comments.

Literature review

Causes of underdevelopment and the potential roles of IoT

In order to understand the role of the IoT in economic development in the Global South, it is essential to understand various causes of development and underdevelopment. Earlier researchers, according to our review of the literature, have identified fundamental and proximate causes of prosperity and poverty.(12) Institutions, culture and geography are arguably fundamental causes of prosperity. Among the proximate causes are physical capital differences, technology differences, human capital differences and the functioning of markets.Moreover, the contributory causes of underdevelopment are interdependent. For instance, the lack of human capital has led to a low rate of physical capital accumulation in the Global South.(13)

Institutions, in particular, deserve elaboration. Among the key challenges faced by the Global South are poorly developed public infrastructure, ineffective governance structures and the lack of properly functioning institutions.(14) Building on the work of Roland, de Laiglesia classified institutions according to the rate of change: 'Slow-moving' institutions include legal infrastructure, culture and social norms, while laws, rules and regulations, contract enforcement, political process and governance are examples of 'fast moving' institutions.(15)

We argue that the IoT could act as a novel solution to address some of the key institutional bottlenecks and compensate for some of the causes of poverty, especially the proximate ones. For instance, grades and standards (G&S) are arguably among the most relevant institutions for the Global South and implicitly reflect the technologies being used.(16) Note that there is a tendency among consumers to demand product quality and safety. Such demands are communicated to the suppliers of products through G&S, which are reflected in certification and labels.(17) Note that standards are 'rules of measurement established by regulation or authority' and grades are 'a system of classifications based on quantifiable attributes.(18) G&S can apply to performance (eg characteristics such as the maximum amount of pesticide residue a product is expected to have at a certain point in the value chain) or processes (eg production of raw materials, processing into intermediate/final goods and marketing). Specifically process standards may reflect different meanings and functions. For instance, they may describe the expected characteristics of a process to achieve a certain level of performance of the product, such as an organically grown fruit or meat product that is safe to consume. They are also related to the creation or maintenance of certain conditions relating to the environment, workers and ethical standards.

Meeting G&S often requires huge investments, which are unaffordable for smallholder farmers. For instance, farmers may need to reduce pesticide use. As a result of the changes in G&S in the 1990s, many small agribusinesses and farms went out of business. In the same period many small dairy operations were forced out of business in Brazil and other Latin American economies because of their inability to meet G&S standards related to the quality and safety of milk products.(19)

The IoT is making it easy to measure and meet standards. For farmers the power of the IoT can be helpful in deploying effective and inexpensive alternatives to pesticides. For instance, wireless sensor networks are being used to monitor pest counts. The Vancouver-based company, Semios, has developed camera-equipped traps to monitor pest activity. The equipment is placed throughout a field, about one per hectare. A central hub delivers this information and weather data to SemiosNET software, which records the data and manages the devices. Semios analysts monitor crops in real time. If the pest population is detected to be too high in a given area, remotely controlled dispensers (about two per hectare) spray pheromones (naturally occurring odourless substances excreted externally by a fertile body, which conveys a signal that triggers responses from the opposite sex). Pheromones manipulate insects' communication pathways and confuse them so that males cannot find females. The pheromone treatments are reported to be non-toxic and cost less than traditional pesticides.(20) Semios described its business model as delivery of a service through the IoT. The use of pesticide thus can be minimised or even avoided completely.(21) As of 2013 Semios was planning its expansion into Latin America.

Barriers related to measurement, implementation, enforcement and transaction costs and the potential roles of IoT

A related point is that institutional bottlenecks such as the lack of G&S lead to transaction cost-related barriers. For instance, there is often a lack of G&S for traditional products in the agrifood chain such as sugar and rice. Direct face-to-face meetings between buyers and sellers are needed

to judge product quality on the spot, which is regulated by informal institutions. Transaction costs and risks are thus high for such products.(22)

To make the above statement meaningful requires a more detailed discussion of what is meant by transaction costs. In the context of business transactions involving two or more parties, for Douglas North, 'transaction costs are…two things: (1) the costs of measuring the dimensions of whatever it is that is being produced or exchanged and (2) the costs of enforcement".(23) He goes on to say that 'a lot of what we need to do is to try to measure the dimensions of what we are talking about in such a way that we can define them precisely'.(24)

A related point is that an implication of institutional bottlenecks is that economies in the Global South are faced with challenges in enforcing commercial contracts, social and economic rights, laws and regulations (eg agro-environmental) and standards (eg pollution-related). Put differently, these economies are characterised by the lack of effective enforcement mechanisms. Emphasising the importance of measurements in enforcement, North argues: 'Without being able to measure accurately whatever it is you are trying to enforce, there cannot be effective enforcement, even as a possibility'.(25) The technology available is among the important factors that affect the costs of measurement and enforcement and hence the transaction costs.(26) In this regard, the IoT can make up for the lack of relevant institutions or the problems associated with high transaction costs.

Advancements in the IoT make measurement of whatever one wants to measure easy, accurate and extremely cost-effective. The idea is simple. Technologies such as electronics, software and sensors are embedded on 'things' (eg machines, devices and appliances, animals or people) and are provided with unique identifiers. The system transfers data about internal states of the 'things' or the external environment with minimal or no human intervention. The physical parameters, activities, dimensions and characteristics that can be measured are not just limited to transactions involving two or more parties: pretty much anything can be measured. For instance, in the context of environmental monitoring and protection, sensors can measure a wide range of environmental parameters, such as pollution, noise, relative humidity, wind speed and direction, air temperature, sea temperature, tide height, salinity and oxygenation (dissolved oxygen concentration) of water, and vehicle speed. In agriculture the sensors can help measure soil and vegetation characteristics such as soil moisture, and available nutrients, organic carbon content, ground vegetation and pH levels.

Enforcements can be implemented at three levels: first-party, second-party and third-party.(27) First, it is important to emphasise that third-party enforcement mechanisms, which are often formal coercive enforcement measures by the state, have been relatively ineffective in the Global South. This increases the relative importance of the first two types of enforcement.

The IoT can make first-party enforcement or self-enforcement attractive and help individuals and enterprises live up to contracts and promises. In this way transaction costs are reduced. Consider the following example. Networked sensors and automated feedback mechanisms are changing the usage patterns of key resources such as energy and water. Such patterns can enable dynamic pricing. Italy's Enel and Pacific Gas and Electric (PG&E) in the USA deploy smart meters, which provide consumers with visual displays of energy usage as well as the real-time costs to

provide it. The cost of producing energy varies substantially throughout the day, which is not taken into account in the traditional residential fixed-price-per-kilowatt-hour billing. With better information about variable pricing based on the time of energy use, residential consumers can make decisions such as shutting down air conditioners or running dishwashers during off-peak times. Likewise commercial customers can shift processes and production that are energy-intensive away from high-priced peak energy demand periods to off-peak hours.(28) The above example is not from the Global South. Nonetheless, it illustrates how the IoT can facilitate first-party enforcement.

In second-party enforcement one party retaliates against the other. The IoT provides a low-cost mechanism for this type of enforcement. For instance, in Kenya the IoT has facilitated second-party enforcement for companies such as M-KOPA and GreenWize Energy, which offer solar lighting products to poor households. M-KOPA sells its solar package for a down payment of about US$30. It is worth $200, which includes $25 in interest; users can pay a daily instalment of $0.50 for one year and then own an 8-watt solar panel, two LED lights, a USB phone charger and a portable solar-powered radio. Most people in Africa are reported to spend $0.50 daily on kerosene. As of November 2015 all M-KOPA's 85,000 customers had paid their loans in full.(29) Each solar panel has a SIM card powered by Safaricom. People can use the mobile payment system M-PESA to pay bills. Sensors have enabled this 'pay-as-you-go' model to serve remote communities. A customer can pay the fee using a mobile phone. If a customer fails to make a payment, the system can be shut off remotely. The power can be switched back after the customer pays the instalments.(30) M-KOPA solar panels can be used to power services such as lighting, cell phone charging and radios.

The existing technology trajectory and the roles of IoT

The attractiveness of new and emerging technologies such as the IoT needs to be evaluated by comparing them with technologies currently used by target users. Most economies in the Global South are characterised by low quality physical capital, such as the infrastructures used by transport and utility industries (eg drinking water supply, highways, rural electrification), plant, equipment and information technology.

Dosi noted that more powerful and less powerful trajectories exist, and argued that, when the existing trajectory is 'powerful', firms and nations might find it difficult to switch to an alternative trajectory.(31) Demand for a new technology such as the IoT is high when the existing alternative technology trajectory is unattractive. Compared to industrialised countries, the adoption of the IoT in the Global South is likely to lead to more significant technical progress.

The economics of the IoT: an illustration from the insurance industry

One upshot of the various institutional bottlenecks, the lack of human and physical capital, technological challenges and other sources of high transaction costs is that Southern economies are characterised by underdeveloped insurance markets.(32) In order to illustrate this point, compare India and the USA. The annual premium income of the Indian general insurance

industry was $12.7 billion in FY 2014–15 or 0.64% of GDP.(33) The total US insurance premiums amounted to $1.1 trillion in 2013 or 6.5% of GDP.(34)

The lack of affordability of insurance for the majority of the population is the primary cause of the underdeveloped insurance market. India's average health insurance premium is twice the per capita spending on healthcare compared to half the per capita spending on healthcare in the USA.(35) Fraud also leads to increased insurance premiums. For instance, one estimate suggested that fraudulent claims account for 10% of total claims in India.(36) In order to understand how the IoT can transform the insurance sector in the Global South, let us consider the demand and supply sides of this industry.

The supply-side condition

It is commercially viable for the insurance company if:

$$\text{Insurance premium} \geq \text{expected loss} + \text{risk margin} + \text{administrative costs} \quad (1)$$

Regarding administrative costs in (1), in the Global South in 1989 such costs for every dollar of insurance premium collected varied from $0.28 in Brazil to $0.54 in Costa Rica, $0.47 in Mexico and $1.80 in the Philippines.(37) Administrative costs are thus substantial and should be considered when evaluating the viability of an insurance company's offerings.

In particular, micro-insurance is not an attractive business for most insurance companies because of high transaction costs, mainly associated with high administrative costs. Consider a farmer who has to pay an insurance premium of $1 to insure seeds worth $10. In the case of bad weather such as drought, an insurance agent may need to visit the farm to verify the farmer's loss. The insurance company also needs do paperwork to pay $10 to the farmer. The insurance company's expense is thus the same irrespective of the amount of the insurance policy, whether it is a $10 or $10,000 policy.

In many cases, however, the main concern is the lack of availability of insurance products, rather than their affordability. As a result of problems such as high costs and moral hazard, individual crop insurance is almost non-existent in the Global South as a tool to insure farmers or farm credits. This point is especially important because, as Adam Smith, in *The Wealth of Nations* was already noting in 1996, in order to provide the desired security to a large number of customers, 'the insurer should have a very large capital'.(38) Most economies in the Global South lack insurers with sufficiently large and diversified asset bases to absorb the costs of high-impact, low-probability external events such as extreme weather conditions.

The demand-side condition

A customer will invest in insurance if(39):

$$\text{expected utility without insurance} \leq \text{expected utility with insurance} \quad (2)$$

Alternatively, the demand-side condition can also be written as(40):

$$U(\text{Benefits of insurance}) > U(\text{Cost of buying an insurance plan}) \quad (3)$$

U(*) is a utility function, which evaluates an insurance plan's benefits and costs in a common metric.

In (3), both monetary as well as psychological costs and benefits need to be taken into account.

$$U (M_b + P_b) > U (M_c + P_c) \quad (4)$$

where,
M_b = Monetary benefits associated with an insurance plan;
P_b = Psychological benefits associated with an insurance plan;
M_c = Monetary costs associated with an insurance plan;
P_c = Psychological costs associated with an insurance plan

Regarding the right side of (2), it is also worth noting that insurance could affect farm household utility through various channels. For instance, insured farmers are likely to feel more secure and less worried (P_b). Income is stabilised if the farm income is not affected by adverse weather or other natural disasters. A farmer with agriculture insurance can also take decisions that can maximise his profits (eg investing in high-return cash crops) because he does not need to worry about potential damage as a result of adverse weather conditions.(41)

A lower priced insurance plan would reduce M_c and hence the right side of (4) for a prospective purchaser of insurance. The psychological costs of regret in buying an insurance policy when no insurance claims needed to be filed, thanks to conditions such as good weather for crops, or the policy holder having no health problems are included in (P_c). Costs associated with privacy are also important components of P_c. In this regard, P_c is lower in societies that rate the perceived costs of privacy as lower than the benefits of information exchange.

Some examples of IoT-enabled insurance business models

We present two examples that illustrate the IoT's effect on the insurance industry in the Global South.

The social enterprise Kilimo Salama

Kilimo Salama (KS, 'safe agriculture' in Swahili), which is a partnership between the Syngenta Foundation, UAP Insurance and Safaricom, has developed an index insurance which uses solar-powered weather stations across Kenya to serve small farmers. Farmers buy the insurance at the beginning of the season for 10%–20% of the amount invested in seeds and inputs. As of 2013, KS had insured over 100,000 farmers in Kenya and Rwanda.(42)

Kenya's weather stations traditionally employed manual rain gauges. KS modernised 32 of them with solar power and computerised gauges. Weather stations are equipped with wireless SIM-cards that transmit data on rainfall levels, sun and temperature every five minutes to a cloud-based server. A farmer who buys insurance is linked to the nearest weather station, which is closer than 20 kilometres. At the end of a season the data are aggregated and combined with satellite data in order to map out rain patterns. KS works with agronomists to calculate the index and identifies the locations that experienced too much rain, too little rain, or rain at the wrong time. Farmer pay-outs are calculated based on crops, location and the amount invested in seeds.(43) If the rainfall is insufficient early in the growing season, or much too late in the corn season, farmers get an automatic pay-out. Farmers are not required to file a claim. In case of

extreme weather that destroys the whole harvest, they get the full amount. No farm visits are necessary.(44) Insurance claims are normally settled within four days.(45)

The insurance is completely automated. The availability of weather stations and cell phones has dramatically lowered the cost of writing policies. KS uses cell phones for signing up farmers and paying out insurance claims. Policies are distributed through dealers, who sell seeds, fertilisers and chemicals to farmers. The dealers are provided with camera phones to record the purchase. They use an advanced phone application with camera and phone functions to scan and capture policy information through a code. The information is uploaded to Safaricom's mobile cloud-based server, which administers policies. Farmers instantly receive information about their policy and pay-outs in SMS messages.(46) Perhaps the most notable feature of this insurance offering is that, at the end of the growing season, pay-outs go electronically to the farmer's cell phone account. Indeed, sending the text message welcoming the new client has been the biggest component of cost associated with providing insurance.(47) The overall effect on farmer welfare is even greater. Thanks to the KS insurance scheme, banks and microfinance institutions are reported to be more comfortable in giving loans to farmers.

China's big data company, Lichengbao

Lichengbao teamed up with small insurers such as Dubon Insurance and China Insurance to launch China's first Usage-Based Insurance (UBI) for cars. It offers customers different non-expiring packages based on driving distance and thus differs from the car insurance model that charges a flat premium per year. The primary targets consist of drivers who drive less than 15,000 km per year, who account for about 40% of Chinese drivers. Through the Lichengbao app, drivers can subscribe to insurance covering 10,000-km driving at a minimum premium of $155. They receive an on-board IoT-enabled smart device, Chebao, for mileage monitoring.(48) Lichengbao had 100,000 users in December 2015 and aims to attract 500,000 customers by 2016. Lichengbao offers safer drivers a mileage bonus, which will help its customers develop better driving habits. It monitors risky types of driving behaviour, such as sharp acceleration and slowdowns, as well as sudden turns.(49)

Other Chinese car insurers have announced that they will start employing a UBI structure in pricing using big data. UBI looks into real-time driving patterns, which are tracked by the analytic systems in cars. Among the players planning to enter this industry are the insurer Ping An and the online insurance company Zhong An. An estimate suggested that UBI in China may exceed $47 billion by 2020, if appropriate regulations are developed and applied.(50)

The IoT's impacts on the insurance industry: an overall assessment

The KS case indicates that the IoT makes it possible to offer small insurance policies to poor farmers by drastically reducing the costs associated with signing people up, verifying claims and paying for the damage. By digitising all the activities, micro-insurers can avoid substantial administrative costs.

Indeed, since the 1990s the focus of the agricultural insurance industry has gravitated towards index-based insurance, which utilises an index (eg area-wide yields or a weather index), that is

correlated with the farmers' yields. Index-based insurance does not pay the policy holder on the basis of individually assessed loss and can thus resolve the key problems associated with individual insurance.(51) First, since payments to the policy holders are based on a sub-regional measurable index, there is no moral hazard. Second, there is no requirement to make a field-level assessment, which reduces costs. Third, as noted above, a major challenge concerns the accurate measurement of the risks involved.(52) The fact that the insurance is based on a reliable and independently verifiable index makes it possible to reinsure, which allows local insurance companies to efficiently transfer part of the risk to the global market.

The Lichengbao case indicates that connected cars allow relevant additional data to be collected, managed and shared, which can be supplemented with human advice to improve safety and prevention. Insurers are thus in a position to provide a better and more accurate understanding of exposure, hazards and risk, which results in the lower expected loss and risk margin in (1).

IoT deployment, with the help of health monitors, smart homes and other devices allows insurers to reward behaviours that reduce risks. For instance, the premium is lowered if a customer regularly locks doors when leaving home, or turns off stoves and ovens when they are not in use. In the non-IoT environment there is no measurable or reliable way for home insurers or car insurers to know this information. It is thus possible to offer loss control on an individualised scale.

In the health insurance sector IoT initiatives such as fitness trackers and smart accessories allow the sharing of information related to exercise habits and food intake. Policy holders thus can demonstrate preventative behaviour which is likely to lead to a reduction in health insurance premiums. Note that IoT-based tools, accessories and services for healthcare are available in the Global South. For instance, in June 2015 the maker of popular fitness wearables, Fitbit, entered the Indian market.(53) The healthcare IoT solutions can make first-party enforcement attractive and help policy holders live up to contracts and promises.(54)

Overall the IoT can bring fundamental changes in the business models and the economics of insurance. By using sensors, real-time feedback and predictive analysis of behavioural data, it is possible to shift the property and casualty insurance business from a 'reimbursement' model to a 'prevention and loss control' model.(55) In this way, the benefits of insurance can be increased and the costs of buying an insurance plan can be decreased.

The overall state of the IoT in the Global South

The analysis presented in the earlier section indicates that some signs of IoT-led transformation have occurred in the insurance industry in the Global South. Indeed, the IoT's footprints can be seen in key areas of economic development, such as agriculture, health and environment. Table 1 lists some IoT application areas currently being explored in these areas.

Table 1. Some key areas of IoT deployment in the Global South.

Area of IoT deployment	Examples
Improving agricultural and food systems	
Improving farming practices to increase yields	Indonesia: CI-Agriculture

	China: AKOL system's fish farms
Managing and controlling temperature, and nutrient and water flows to plant roots	Vietnam: NETAFIM
	Kenya: Ez-Farm
	China: Tianjin's intelligent engineering system to control greenhouse temperature and air
Improving the quality and safety of agricultural and food commodities	China: Baidu's smart chopsticks to detect contaminants in food
Enhancing environmental security and resource conservation	
Monitoring pollution and administering preventive measures	China: Green Horizon
Reducing congestion in transportation networks	Vietnam: Da Nang's prediction and prevention of congestion on roads, and to coordinate responses in case of adverse weather or road accidents
Improving indoor air quality	China: Philips' Smart Air Purifier
Promoting energy efficiency and conservation	China and South Africa: WEMS wireless sensors and controllers to monitor and adjust a building's energy usage
Protecting wildlife and plants	South Africa: South Africa National Parks' (SANParks) Intensive Protection Zone
	Indonesia: use of old Android cell phones encased in solar panels in trees in rainforest in Sumatra
Improving healthcare, public health and medicine	
Improving telemedicine and remote patient monitoring	UAE: home-monitoring system launched by Etisalat and Enayati Home Health Care in Dubai
Improving record keeping and databases in healthcare	Kenya, Uganda, Benin and Zambia: VaxTrac's registry
Monitoring water supply and quality	Vietnam: Da Nang Water Company's (DAWCO) real-time analysis and monitoring of water supply
Enhancing efficiency, monitoring and taking corrective measures in manufacturing, retail and distribution industries	
Enhancing efficiency	China: deployment of industrial robots
Monitoring and taking corrective measures	China: system designed by IBM and Lushang Group to ensure the safety of pork products
Eliminating the distribution and retailing of counterfeit products	China: deployment of RFID in stores to allow consumers to verify the authenticity of products

Improving agricultural and food systems

Among the proximate causes of poverty in the Global South are the dominance of inferior technologies and the lack of physical and human capital.(56) An encouraging sign is that IoT-based solutions are replacing the inferior technologies used in agriculture.

Improving farming practices to increase yield

Indonesia's Collective Intelligence Agriculture (CI-Agriculture) has developed precision farming techniques in which the IoT is the main component. In 2014 CI-Agriculture began its trial on a rice paddy near Jakarta at the foot of Mount Gede. For four months CI-Agriculture experimented

with drones and weather sensors. During the planting season soil conditions were monitored and aerial photographs were created.(57) It has developed agricultural management systems which analyse data related to weather and soil conditions, as well as satellite imagery and drones. Based on the trial, CI-Agriculture decided to focus on three products.(58) One of its products is Crop Accurate, which uses sensor systems, drones and remote sensing to collect data that can be used by the smart farming systems. It gives advice regarding the best time to plant, fertilise and use pest control. The technology is scalable, which means that it is possible to use sensors for a large area. Agricultural data will be collected and analysed on a regular basis to predict crop yields. At the end of each season the smart farming system analyses the data and provides recommendations to improve farming in the next season.

To take another example, in April 2015 Chinese agricultural authorities signed a deal with AKOL to deploy AKOL's 'agricultural cloud' technology for fish farms. Through the AKOL system fish farmer operators can access in-depth information, gathered via sensors, and analyse it. The system instructs the fish farmers the appropriate time to clean pools, the amount and time to feed fish and other information.(59)

Managing and controlling nutrient and water flows to *plant* roots

Low quality technology is also being replaced with superior technology in the management and control of nutrient and water flows.(60) Ez-Farm, a water management solution for agriculture, which was designed by water research scientists at IBM Research-Africa targets telephone farmers, who live in cities and can visit farms only at the weekends. These farmers need better reports on water usage and other aspects of operations. Farms have water tank sensors, soil moisture sensors and infrared light sensors, which monitor the health of plants. As of July 2015 the tool was being piloted. IBM had set up pilot projects with farms around Nairobi where sensors send data to IBM's cloud-based data centres every minute. Using big data, and via apps on smart phones and tablets, the system delivers information to farmers and water service providers on a real-time basis about current and predicted water and soil moisture levels.(61) Future plans involve incorporating data from the Kenya meteorological department and other sources. For instance, information about rainfall patterns and predictions will be delivered to farmers' cell phones. Additional data about farms, such as the real-time operating status of farm equipment (eg pump failure) will also be provided in the future, which will help save costs.(62)

In August 2015 Vietnam's biggest privately owned company, Vingroup, signed a $17 million agreement with Israel's NETAFIM, which provides turnkey greenhouse projects, drip and smart-irrigation solutions.(63) NETAFIM's drip irrigation system can control nutrient and water flows precisely. It does so by wirelessly monitoring the flows with atmospheric sensors. It also utilises self-cleaning pipes which are installed under the surface, and which can reduce water loss through evaporation and lessen the severity of contamination from surface water run-off.(64) According to the agreement, NETAFIM will supply VinEco with greenhouse structures, drip products, automated systems for climate control, crop growing platforms, know-how, and agronomic and other support services.(65)

China has undertaken various IoT projects to increase farm productivity and enhance standards for quality and safety of agricultural and food commodities. In Tianjin a project involves an intelligent engineering system, which is designed for artificial control of greenhouse temperature and air. It collects data and sends out warnings when the temperature falls below a certain critical level during the winter season.(66)

Improving the quality and safety of agricultural and food commodities

A significant proportion of milk, meat, rice, vegetables and other food items sold in China is heavily tainted and contaminated. The IoT can drastically change the transaction costs of engaging in opportunistic behaviours of various parties engaged in the food supply chain. The Chinese government has made food safety a top priority. A project in Tianjin involves monitoring micro-organisms in milk at each stage 'from cow to table'. The monitoring is expected to enhance transparency and strengthen the reputation and competitiveness of dairy companies.(67)

In 2011 Fudan University's Auto-ID Lab collaborated with 17 other research teams at universities, research institutes and enterprises on a project called the Agriculture Internet of Things and Food Safety and Quality. The project was supported by the Ministry of Science and Technology, which uses the IoT to track agricultural products from the field through the supply chain and food-processing environments.(68) Businesses are also responding by developing products that monitor food safety. For instance, Baidu announced a plan to launch a pair of smart chopsticks that can detect contaminants in food.(69)

Enhancing environmental security and resource conservation

Institutional bottlenecks and various causes of underdevelopment noted above, such as poorly developed public infrastructure, ineffective governance structures and the lack of properly functioning institutions,(70) have led to urban ills such as traffic congestion and air pollution in the Global South.

Monitoring pollution and administering preventive measures

Beijing's IBM Green Horizon provides a high-profile example of the deployment of the IoT, machine learning and artificial intelligence (AI). The $160 billion initiative was first launched in July 2014 to help the Chinese government achieve its environmental targets over a 10-year period. The targets included: (1) reducing fine air pollution particulate matter (PM2.5) concentration by up to 25% by 2017;(71) (2) increasing the proportion of renewable energy to 15% by 2020; and (3) achieving a 45% reduction in carbon intensity by 2020.(72)

Green Horizon relies on real-time data from optical sensors, weather satellites and meteorological data, other structured databases, the cloud, big data analytics and the IoT in order to gain deeper insights into the type, source, dispersion and levels of the city's pollutant emissions. The system also makes optimisation and adjustment to better utilise renewable energy sources. In addition, it uses cognitive computing analyses and learns from real-time data and information.(73) According to IBM, the system uses 'adaptive machine learning', which

constantly learns ways to improve a forecast for different time horizons and different locations of a city, using different models.

Using the climate modelling technologies, it is possible for the Beijing municipal government to predict 72 hours in advance the location where harmful pollutants are likely to spread. IBM researchers were reported to be working to expand the system's capability to provide medium- and long-term forecasts as far as 10 days ahead.(74) Such predictions will help the city to perform a scenario analysis that looks at the effects of various short-term policy options, such as traffic restrictions, mandatory installation of filtering systems and relocation of facilities. They can also provide relevant information to residents so that they can avoid specific areas in the city. Information can also be posted on electronic freeway signs. The traffic can be diverted to less-congested and less-polluted areas. It is also possible to work with factories to plan and synchronise production cycles.(75)

IBM's China Research Laboratory has led the effort. It is utilising the expertise, knowledge, experience and resources of IBM's 12 global research labs and partnering with government, academia and the private sector. In December 2015 IBM announced four more partnerships to deploy Green Horizon: two in China (Baoding, Zhangjiakou), one in India (Delhi) and one in South Africa (Johannesburg).(76) It was reported that the majority of IBM's customers for smarter cities technology are in countries of the Global South such as China, India, Indonesia and Vietnam. In China IBM is reportedly focusing on smaller cities with populations of about one million. Traffic problems are more difficult to solve in the largest cities such as Shanghai and Beijing.(77)

Reducing congestion in transportation networks

One example of a city using the IoT to address congestion problems in transportation networks is Vietnam's Da Nang, which is a major port city on the South China Sea coast next to the Han River. Da Nang uses big data for predicting and preventing congestion on roads, and to coordinate responses in case of adverse weather or accidents.(78) Data are aggregated from multiple sources. Sensors embedded in roads, highways and on buses detect anomalies and control traffic flow.(79) The system also gives the Department of Transport access to real-time information for its fleet of buses. From the city's traffic control centre city officials can monitor traffic and control the traffic lights system. In case of congestion resulting from an accident, traffic lights can be adjusted, which allows time for cars affected by the jam to pass through. Such data are accessible to passengers through video screens at bus stations or via mobile apps.(80) Users can see details such as the location of a bus, speed and predicted time of a trip. The plan in the future is to alert citizens to how crowded a bus is likely to be when it arrives. The Vietnamese government wants to discourage the country's growing middle class from buying cars. One way to do so is to make the public transport system more reliable and efficient.(81) Da Nang's transport grid was established based on people's movement patterns and on the city's growth pattern.

Improving indoor air quality

China's AliCloud supports Philips with cloud computing services to store and process the data of Philips' connected products and solutions in China. In October 2014 the Smart Air Purifier was launched in China, which was Philips' first connected product supported by AliCloud. People living in big cities and those affected by allergies or respiratory conditions are particularly concerned about their homes' air quality. People can use the Philips Smart Air to monitor air quality in their homes as well as to access the reported city air quality index data such as the PM2.5 index. The Smart Air Purifier can be operated in real-time from anywhere at any time. It sends alerts to users' mobile device when the indoor air quality reaches unhealthy levels or when the filter needs replacement.(82)

Promoting energy efficiency and conservation

The UK-based building energy management company, Wireless Energy Management Systems (WEMS) offers its products in China and South Africa. WEMS provides a range of wireless sensors and controllers to monitor and adjust a building's energy usage. These can be used to reduce lighting if it is bright outside and reduce temperature levels if it is warm. The system can be monitored remotely.(83)

Protecting wildlife

As in other areas of development, the lack of human and physical capital has been a hindrance to protecting wildlife.(84) For instance, South Africa's Kruger National Park, which has an area of 20,000 km^2, has only 400 rangers.(85) One estimate suggested that 80% of poachers in Kruger National Park in 2014 came from Mozambique. The fence along the Mozambique border has not served as a means of preventing human infiltration.(86)

In an attempt to facilitate surveillance, early warning and detection, in October 2014 South Africa National Parks (SANParks) started a two-year project to build an Intensive Protection Zone in the south of Kruger, where 60% of the park's rhino population lives. Boundary fences are going to be fitted with motion sensors to track movement and send GPS coordinates to an operations centre. Rangers will be deployed by truck or helicopter in the case of a security breach. In the Park's 220-mile border with Mozambique a gunshot detection system, known as ShotSpotter has been developed and implemented since May 2013.(87)

As another example, Intel's credit card-sized Galileo motherboards with 3G communication and storage have been attached to critically endangered black and white rhinos in Africa. The project is a partnership between Intel South Africa and the cloud company, Dimension Data. The Galileo board is an ankle collar with a rhino-proof case. A RFID chip is placed on a rhino's horn. Vodafone has provided the connectivity. Anti-poaching teams are contacted if the two pieces become disconnected. In the next phase the project team hopes to monitor rhinos' heart rate and other vital indicators, so that poachers can be caught before they kill the animals.(88)

According to the Rainforest Action Network, Indonesia loses over a million hectares of forest each year. The Indonesian rainforest is home to many unique species of plants and animals.(89) NGOs and activists have come up with IoT-based solutions to protect these resources. In 2013 the US-based Rainforest Connection teamed up with the Zoological Society of London to install

old Android cell phones encased in solar panels in trees in the rainforest in Sumatra. Each phone can catch the sound of a chainsaw within one square mile of its location. The sound and location data are sent to the cloud, and rangers patrolling the forests get an alert.(90) Some of the phones were used for five years before being deployed in the project.(91) The system has also been deployed in various sites in Cameroon to monitor 10,000 hectares of rainforest. It can detect audio signals associated with logging and poaching (eg a chainsaw's whine, a gunshot, and the sound of a logging truck) and alert local authorities.(92)

Satellite imagery is being used to monitor forests. Nonetheless, detecting new areas of deforestation from satellite imagery often takes many days. The old cell phones have thus been an effective tool for taking quick action against logging and poaching. According to Rainforest Connection's estimate, each cell phone can protect 300 hectares of endangered forest, which may prevent the release of 15,000 tons of CO_2.(93)

Improving healthcare, public health and medicine

Various institutional bottlenecks and the lack of physical and human capital have led to inadequate healthcare infrastructure in the Global South.(94) The IoT can alleviate this problem via various mechanisms.

Improving telemedicine and remote patient monitoring

In the early 2015 the UAE's telecommunications operator, Etisalat, and Enayati Home Health Care launched a home-monitoring system on a pilot basis in Dubai. The system was developed by the British company, Equivital, which focuses on the IoT. The system allows Enayati's healthcare staff to monitor huge amounts of physiological data from their patients from the sensors in the patient's body. The data can be collected on a real-time basis or retrospectively.(95)

Improving record keeping and databases in healthcare

African healthcare clinics' problems include poor record keeping and inadequate databases. Most clinics do not have proper and reliable means to identify patients who have received treatments, such as inoculations and vaccines. Because of this, wastage rates are reported to exceed 50% in some clinics. In order to improve this situation, the US-based non-profit organisation VaxTrac has created a registry in Kenya, Uganda, Benin and Zambia. Patients returning to clinics in these countries can access their vaccination records by touching a biometric sensor. Their inoculation history is stored on a mobile-phone-based vaccination registry.(96)

Monitoring water supply and quality

According to the *World Water Development Report 2012*, inadequate water supply, sanitation and hygiene lead to about 3.5 million deaths annually, the majority of which occur in the Global South.(97) The IoT can be used to monitor water supply and quality. One example is Vietnam's Da Nang Water Company (DAWCO), which uses big data to provide real-time analysis and monitoring of the city's water supply.(98) The goal is to manage the system better by detecting

leaks and accurately forecasting future demand. In the past the DAWCO needed to collect water samples manually. The big data project involves installing sensors throughout each stage of its water treatment process. Managers can track the water's turbidity, salinity, pH, chlorine and conductivity levels in real-time. They receive alerts and notifications when these readings indicate sudden changes.(99)

Da Nang has teamed up with Intel to construct a modern green data centre. The Da Nang People's Committee introduced over 135 e-government services, ranging from school admissions to property registration. Sensors also monitor water levels in the Han River, which has a high flood risk associated with sea level rise and other factors.(100)

Monitoring and taking corrective measures in the manufacturing, retail and distribution industries

The lack of manufacturing efficiency is a key challenge facing economies in the Global South. A source of manufacturing inefficiency is inappropriate technologies often imported from developed countries.(101) Southern economies are also characterised by a heavy reliance on labour-intensive systems of production.(102)

Enhancing efficiency

The manufacturing sector, which is one of the fastest growing sectors in the Chinese economy, is reported to be one of the major drivers of the IoT market. Analysts say that, because of its large and growing industrial and manufacturing base, China is likely to benefit tremendously from the deployment of the IoT in the manufacturing domain. Indeed, the IoT will greatly facilitate and improve manufacturing in the factory, as well as the distribution of products.(103) Rapidly escalating labour costs, both wage and non-wage, have made China increasingly expensive as a manufacturing hub. For instance, the minimum wage in the city of Shenzhen rose by 64% during 2012–15. Estimates suggest that, by 2019, labour costs will be 77% higher than in Vietnam and 118% higher than in India. Unsurprisingly industrial robot sales in China grew by about 60% in 2013 and the country became the largest buyer of industrial robots.(104)

Monitoring and taking corrective measures

RFID tags are used to track and monitor the flow of the manufacturing process.(105) In 2011 IBM and China's Lushang Group announced that they had built a system to help ensure the safety of pork products in Shandong Province. IBM China Development Lab and China's National Engineering Research Centre for Agricultural Products Logistics created an IoT-based pork monitoring and tracking system. Every pig at a slaughter house is tagged with a bar code with a unique serial number. The bar code follows the products after they are packed and move through the supply chain. In addition to tagging, cameras monitor the production process before shipping. During distribution temperature and humidity sensors are deployed to ensure safe transportation, and global positioning and geographic information systems are used to track locations. If threshold conditions are exceeded, the system sends an alert to take corrective action. Retailers' enterprise resource planning (ERP) and point of sale systems are connected to the Lushang Group platform, which allows the tracking of every item sold.(106)

Eliminating the distribution and retailing of counterfeit products

Another institutional drawback in Global Southern economies is the weak intellectual property rights (IPR) regime. Thanks to China's poor IPR enforcement, merchants and consumers are concerned about counterfeit products in diverse industries such as food, clothing, medications and electronics. To address such concerns, stores have begun to deploy RFID, which allow consumers to verify the authenticity of products. For instance, when buying a product, consumers can use a low-cost reader installed in the store to read products' tags. Brands have started tagging products to facilitate this process. A large liquor company uses RFID to tag and track its high-value products. A store receiving the liquor company's products uses a RFID interrogator to capture the ID number encoded to a bottle's tag. The store can then access the liquor company's server to confirm that the ID matches that of a genuine product. Manufacturers of clothing, furniture and food products have made similar uses of RFID. A maker of hot sauce has deployed RFID tags, which enable customers to use a store's RFID reader to authenticate its products.(107) The use of tags on merchandise in stores is increasing thanks to the decline in the cost of readers and an expectation that most smartphones in the future will have built-in RFID readers.(108)

IoT as a key opportunity to address the challenges facing the GS

The IoT can address key economic, social and environmental challenges and holds great promise and potential to address some of the causes of poverty noted above.(109) Analysts have noted that data created by industrial equipment such as electrical tools, hand tools, drones, office equipment, heaters, generators, wind turbines, jet engines and MRI machines (also called the industrial internet), have a higher potential business value compared with the same amount of data associated with the social media and consumer internet.(110)

IoT-led technical progress can be defined in terms of a shift in the production possibilities curve, and/or an increase in the number of producible goods.(111) In this regard, one estimate suggested that, by introducing IoT and big data-based analytics to track, monitor and manage operations equipment and other assets, the productivity of industrial processes could be increased by as much as 30%. A water utility company installed smart meters and sensors on pipes, treatment facilities and other operational assets with analytics leveraged to predict leaks and adverse weather events and other critical situations. The company expected to save on scheduled repair and overall maintenance costs.(112)

There are already some encouraging signs. A study by McKinsey suggested that about 40% of the IoT's worldwide market value will be generated in the Global South by 2020.(113) These economies are also likely to surpass the industrialised countries in terms of the number of IoT deployments. It is estimated that manufacturing, transportation, smart city and consumer applications currently account for more than 50% of IoT activities. By 2020 the IoT is likely to be pervasive across all economic sectors and processes.(114) Some of the key areas of IoT deployment in the Global South are likely to be mining, oil and gas drilling, construction and manufacturing.(115) Nonetheless, the economic sectors associated with agriculture, healthcare and environment are likely to undergo significant transformation and restructuring.

Economies in the Global South have fewer legacy issues to grapple with and thus have the potential to leapfrog the industrialised world in some areas of IoT applications.(116) Consider the primary sector of the Chinese economy. One estimate suggested that 266 million people or 35% of workers in China are employed in primary sector activities such as agriculture, forestry and fisheries. A study has indicated that, while South Korea has less water and arable land than China, output per farmer in South Korea is 40 times higher than in China. One key factor behind higher farming productivity in South Korea is farmers' heavier utilisation of machinery.(117) The fact that most Chinese farmers do not use machinery makes the IoT-related innovations more attractive for them. Thus, the IoT is likely to offer higher relative advantage to Southern farmers than to those in industrialised countries.

The IoT has the potential to rapidly transform healthcare and the practice of medicine in the Global South. For instance, the IoT could take the current practice of telemedicine to the next level. Sensor-based systems can be used to monitor critical health parameters in healthcare facilities such as hospitals, nursing homes, medical centres and clinical laboratories, as well as remotely. The deployment of IoT is also likely to address problems related to access to healthcare services. Remote patient monitoring via sensors embedded in clothing or worn on the arm or wrist is increasingly becoming the norm.(118)

By adding RFID tags to medication containers, producers, consumers and regulators can be better informed about the drug supply chain. The tags can also be embedded in their medication. The IoT devices and processes may reduce drug development costs and make drugs safer, which can help drug companies and healthcare providers reduce risks and losses.(119) Likewise, by collecting information from medical equipment such as magnetic resonance imaging (MRI) scanners, ultrasound systems and CT scanners, preventive maintenance can be made more efficient.(120)

A major IoT-led transformation is also likely to occur in environmental protection and resources conservation. The IoT is likely to play a key role in protecting rhinos, elephants and other endangered species in Africa. An initiative called Project Real-time Anti Poaching Intelligence Device, which is supported by the International Humane Society, entails monitoring the animals' heart rates using sensors and combining the information with satellite signals. Information is transmitted to the anti-poaching team, which monitors the activities using video-streaming. The plan is to monitor hundreds of square miles of terrain. When the monitor indicates an increase in the heart rate or signals other types of distress, the anti-poaching team gets a notification. The team can then check a video camera which is installed on the rhino's secondary horn. If the animal is wounded, a helicopter is sent to the location with the help of the GPS coordinates.

From the privacy standpoint businesses and consumers in different countries face different structural conditions. In the context of the IoT, consider a study of the media agency Mindshare conducted in 19 economies to assess consumers' attitudes towards connected devices. Only 20% of Chinese consumers were against sharing data with companies because they 'find it creepy'. The global average was 38%.(121) This means that, for Chinese consumers, the degree of distrust of businesses handling their data is not as high as in the West. One way to view Chinese consumers' higher degree of acceptability of IoT-enabled products is to say that China has an

institutional advantage compared to other countries in the IoT domains. A similar point can be made about other Asian economies such as South Korea. The implication is that some technologies that are problematic because fo privacy concerns in the West and hence face implementation challenges are finding their market in Asia**.** An example is an algorithm developed by the US-based ZestFinance, which reportedly uses 'tens of thousands of data points' to assess potential borrower's ability to pay back loans. China's JD.com was reported to be the first customer of ZestFinance.(122) An intriguing aspect of the development of South Korea's New Songdo City is that most of the core technologies were developed in the USA rather than in Korea. Supportive institutions, including lower privacy concerns, are arguably the primary reason why the US-developed smart city technologies were first implemented in Korea.(123) For instance, while the use of sensors such as RFID to automate tracking and monitoring the movements of people is a big concern in the West, such concerns are less prominent in Asia.(124) A research director in Palo Alto put the issue this way: "There is an historical expectation of less privacy [in Korea]".(125) Observers have also noted that, whereas ubiquitous computing is controversial in the West because of privacy concerns, and widely feared as a surveillance tool, in Korea and other Asian nations the concept is viewed as an opportunity to attract foreign investment by showing off technological prowess.(126) The IoT and ubiquitous computing are arguably viewed as technology experiences in Asia rather than as an invasion of privacy.(127)

Challenges and risks associated with IoT deployment

The various sources of poverty, as noted above,(128) can also act as barriers to full utilisation of the IoT in economies of the Global South. Infrastructural challenges are the most daunting in most such economies. In the examples discussed above, to protect rhinos in Africa, key challenges are connectivity and battery life. Sending video is a bandwidth-intensive task and most satellites are not equipped to deal with high bandwidth in real time. Likewise the batteries of most GPS packs attached to the animals do not last more than nine months.(129)

The IoT presents special security risks primarily because of its relative newness and unproven track record. Earlier research has suggests that cybercrime's footprints across the Global South are getting bigger.(130) There has been a lack of clear focus on cyber-security in the IoT, which means that in the future IoT devices are likely to become larger and more attractive targets for cyber-criminals, nation-states and cyber-terrorists. In 2014 a cyber-security researcher showed that about 200,000 traffic control sensors in major cities such as Washington DC, New York, San Francisco, Seattle, Lyon and Melbourne were not encrypted and thus were vulnerable to cyber-attacks. The researchers demonstrated that it was possible to intercept information coming from these sensors from 1500 feet away, or by a drone.(131)

Regarding the technology differences as the causes of prosperity and poverty,(132) it is worth noting that technologies in the Global South are relatively outdated and inferior**.** IoT devices are even newer phenomena in the Global South. Moreover, less attention is being paid to cyber-security in these countries.

Interoperability and standardisation challenges are also faced by organisations. Many vendors are building 'silos' that do not easily interconnect or share information.(133) The IoT-related

standards are currently fragmented among the relevant new technologies to ensure the interoperability of communication protocols.(134) For instance, healthcare organisations face the challenge of integrating data from consumer-based sensors – such as internet-based blood pressure monitoring systems and weight scales – into the overall IT architecture. These systems present data exchange problems: home devices may not have the same level of accuracy and need to be recalibrated.(135)

Given recent media concerns about the use of IoT as a potential spying tool by government agencies, this technology raises genuine privacy concerns. In February 2016 the US Director of National Intelligence, James Clapper, reportedly said: 'In the future, intelligence services might use the [IoT] for identification, surveillance, monitoring, location tracking, and targeting for recruitment, or to gain access to networks or user credentials'.(136)

The lack of democratic institutions and mechanisms can be considered to be among the fundamental causes of underdevelopment.(137) Such conditions may lead to potential misuse and abuse of the IoT in authoritarian regimes. Whereas strong legal protections for the privacy of personal information exist in the EU and clear laws exist as to how data can be collected, stored and reused, privacy is a 'new luxury' in most cities in Asia and other parts of the world.

State surveillance and potential violation of the right to privacy are likely to be key concerns in some authoritarian regimes such as those of China and the Persian Gulf. In 2011 the Chinese government announced a plan to introduce an 'information platform of real-time citizen movement'. The stated goal of the plan was to tackle congestion by monitoring the flow of people. Human rights activists expressed concerns that the regime could use the information to suppress activists. For instance, cell phones of activists have allegedly already been tracked by security forces, in order to locate activists and know whether others are visiting locations where the activists have visited.(138)

Similarly authoritarian regimes of the Persian Gulf view surveillance and data mining as a means to increase their power and control over terrorists, criminal outfits, minority groups and migrant workers.(139) Some types of data in authoritarian regimes may be collected for spying on citizens rather than providing better services to residents. The IoT thus raises serious human rights concerns in some countries.

Some of the causes of underdevelopment, such as a lack of human capital, also affect the ability to benefit from the IoT. The Global South needs to deal with a talent deficit in this area. The labour market in these economies faces challenges on two fronts. First, there are not sufficient big data engineers and scientists able to perform analytics. Second, many analytics consultants tend to lack capabilities in understanding, interpreting and putting the data to work. Some estimates suggest that India will soon experience a shortage of one million data consultants. India's analytics professionals are reportedly paid 50% more than other IT workers.(140) Big data manpower with high-level strategic thinking capability has been a particular challenge in these countries. For instance, China has a rich endowment of big data human resources thanks to an abundant supply of engineers. However, the country lacks experts at the executive level.(141) A similar point can be made about India.

Discussion and concluding remarks

The IoT industry is only at the early phase of development. Since the Global South is made up of a large and heterogeneous group of countries, the examples presented in this article are not necessarily representative of the area as a whole. Nonetheless, the above analysis has provided important insights into the potential of IoT-led economic, social and environmental transformations, as well as the opportunities and challenges for the Global South in the deployment of this technology.

The IoT has opened a wide range of opportunities in the Global South. Accurate and cost-effective measurements allow the adoption, enforcement and implementation of various measures to enhance the economic, social and environmental outcomes in the Global South. The incremental value of the IoT is thus high in settings characterised by hollow, or defective, institutions.

The diverse applications that are possible with the IoT make it an attractive tool to address a number of developmental problems. The visible impacts of the IoT are already in evidence in primary industries, such as agriculture, forestry and mining, as well as in financial services industries. The IoT is likely to play a key role in protecting wildlife, their habitats, landscape and ecosystems, conserving biodiversity and securing sustainable economic development.

The IoT offers the potential for higher value addition and higher productivity in the Global South thanks to the lack of a legacy system. Organisations can bring fundamental changes in business models taking advantage of the IoT. Opportunities and prospects for the IoT, however, differ across economic sectors.

North argued that ‘we have much more imperfect abilities to structure international markets than we have to structure national markets, where there are rules of the game and enforcement mechanisms that are clear and unambiguous’.(142) The upshot is that GS-based farmers often face difficulty in accessing the industrialised world market**.** In this regard the IoT could promote greater transparency and accountability, which would help farmers in the Global South to expand their markets. Access to precision data helps them export products to the advanced economies of the EU and USA. There are differing standards regarding the amount of pesticides used on crops and the kind of feed or fertiliser given to animals and plants. There are also concerns about the use of child or slave labour to pick crops or produce milk or eggs.(143) Regulators, customers and other stakeholders are also interested in knowing how cows are milked or hens in the egg-laying stage are warehoused. For instance, animal activists have been pressuring poultry farming companies to stop the practice of warehousing egg-laying hens inside tiny wire cages.(144)

With respect to privacy issues, the providers of the IoT need to pursue cross-national and cross-cultural comparisons systematically in order to evaluate the fit of IoT initiatives associated with a given model. Institutions in a country shape the ways in which the IoT is developed and deployed. For instance, alternative utopias of smart cities have been offered. One possibility is ‘a perfectly controlled, perfectly efficient, safe smart city’.(145) A smart city taken over by computers designed by a big technology company is likely to function like a machine. This

highly automated and highly centralised model is efficient but may perform poorly on privacy protection.(146) Authoritarian governments are likely to prefer such a model.

Centralised models are, however, likely to be opposed by societies in which privacy issues are salient. An alternative model is ‘a very decentralized, very redundant kind of infrastructure’, in which services created using digital technologies such as sensors and other IoT devices lead to increased social interaction and sustainable behaviours and reinforce the development of ‘culture, creativity, and wellness’.(147) Countries with high levels of social trust among citizens and a strong civic society and democracy are likely to prefer such models.

Privacy is not a big issue in Asia, since Asians exhibit a higher tendency to trust corporations with personal data. For this reason some US companies have needed to export their ubiquitous systems to countries with more trusting people, such as South Korea, for experimentation.(148)

Public policy measures are important in promoting the growth of the IoT industry and market. The lack of standardisation is a key problem facing widespread diffusion of the IoT. In this regard the Chinese government is shaping the standardisation processes through its role in control and coordination. In the food industry China has implemented the ‘National Food Quality Safety Traceability Platform’, which was a result of collaboration of the Chinese government with the food-production and ICT industries. The Platform utilises the IoT to improve the quality and safety of food-production supply chains. In order to ensure the traceability of food-safety information, it uses the Handle System of the Digital Object Architecture. A key feature of the Architecture is that each digital object has a ‘unique persistent identifier’.(149) Malpractice can be traced to the exact source and the responsible company can be identified. The dairy industry was the first to implement the Handle System, which is expected to be adopted by other sectors in the food industry.(150) The Chinese government has selected the Handle System as the core technology for major national projects such as the National Food Quality Safety Traceability Platform and National Public Service Platform for IoT Identifier Management.(151) This platform will make the Handle System available to all industries in order to trace the identity of goods, producers and processes in the supply chain.

Developing a good IoT ecosystem is key in attracting new businesses. It was reported that a reason why Rose Goslinga, KS founder, chose Kenya was the popularity of the mobile payment system (M-PESA) in the country.(152) With the deepening penetration rates of cell phones and mobile money such as M-PESA in Africa, the markets for KS insurance products are likely to widen.

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